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An Improved Active High Pass Filter

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ABSTRACT

A new active high pass filter, comprising of two general purpose operational amplifiers (OA's), five resistors and one capacitor is presented. The analytical expressions are obtained and the performance of the proposed circuit is examined in relation to the conventional circuit. Simulation and experimental results are presented which establish the superiority of the proposed high pass filter over the conventional circuit.

Keywords: Operational amplifier, Active filter, Active high pass filter.

INTRODUCTION

An active high pass filter using operational amplifier (OA), as shown in Figure 1, find numerous application in various areas of circuit designing.

A straight forward analysis of the active high pass filter, shown in Figure 1, gives

$$\mathrm{H}(s) = \frac{v_o}{v_s} = G.\frac{sR_1C_1}{s^2G\tau R_1C_1 + s(R_1C_1 + G\tau) + 1} \tag{1}$$

where $G = 1 + \dfrac{R_F}{R}$ *and* $s = j\omega$

Different methods have been used to improve the frequency response of active filters[1-6]. The present work aims at improving the frequency response of the high pass filter by minimizing its magnitude error. Such efforts have already been made with success and have been reported in the literature[6-10].

From Equation (1), it is possible to express the magnitude of H(s) as the sum of two components:

$$|\mathrm{H}(s)| = \mathrm{H}_o[1 + \varepsilon_H(s)] \tag{2}$$

where $\mathrm{H}_o = G$ and

$$\varepsilon_H(s) = -(1 + \omega^2 G^2 \tau R_1 C_1) \tag{3}$$

is the magnitude error.

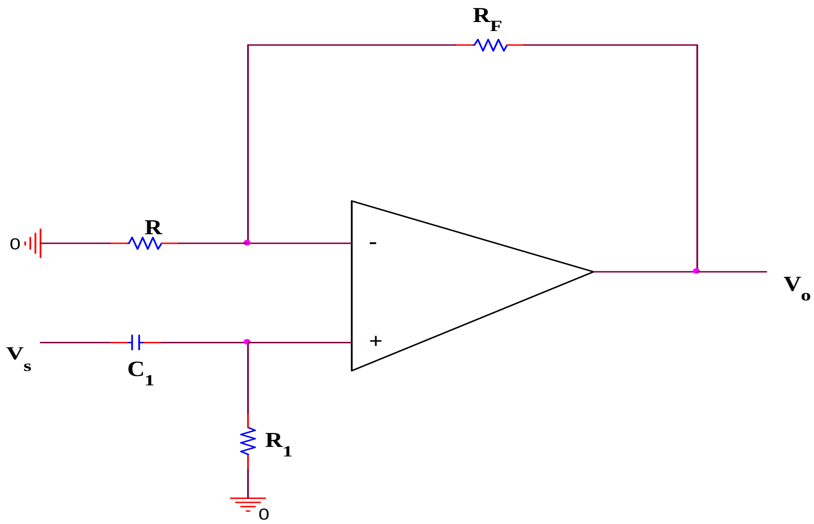


Figure 1. Conventional High Pass Filter

From Equation (3), it follows that the magnitude error is a second order term. In this paper, a new active high-pass filter, comprising of two op-amps, five resistors and one capacitor is presented. Analytical expression is obtained and the necessary condition is derived to realize the maximally flat magnitude response. The feature of this new active high-pass filter is compared with the conventional high pass filter, comprising of one op-amp, three resistors and one capacitor.

PROPOSED HIGH PASS FILTER

The proposed high-pass filter circuit is shown in Figure-2. Assuming the op-amps to be identical a straight forward analysis of the circuit shown in Figure-2 gives

$$\mathrm{H}(s)=\frac{v_o}{v_s}=\frac{G[1+(1+k)s\tau]sR_1C_1}{s^3R_1C_1G\tau^2(1+k)+s^2[G\tau^2(1+k)+R_1C_1G\tau]+s(R_1C_1+G\tau)+1} \tag{4}$$

Note that the transfer function in Equation (4) exhibits poles and zeroes in the left-hand s-plane and further, that the denominator in Equation (4) satisfies the Routh-Hurwitz stability criterion[11].

Using Equation (4), the maximally flat magnitude response is obtained when

$$k=k_m=-1 \tag{5}$$

With this value of k, the magnitude error $\varepsilon_H(s)$, defined by Equation (3), may be approximately put in the form

$$\varepsilon_H(s)=-[1+\omega^6R_1C_1\tau(R_1C_1+G\tau)^2] \tag{6}$$

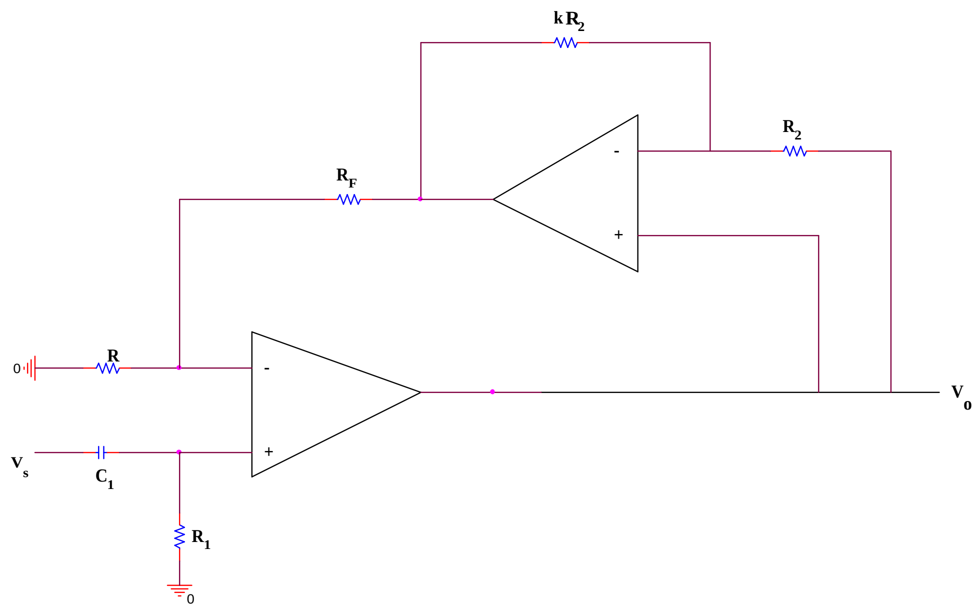


Figure 2. Proposed High Pass Filter

It is seen from Equation (6) that the magnitude error is a sixth-order term, a distinct advantage over the conventional circuit where the magnitude error is a second-order term.

SIMULATION AND EXPERIMENTAL RESULTS

The proposed circuit was tested in the laboratory using the following values of the components:

$R_1 = 470\Omega, \quad C_1 = 0.001\mu F$

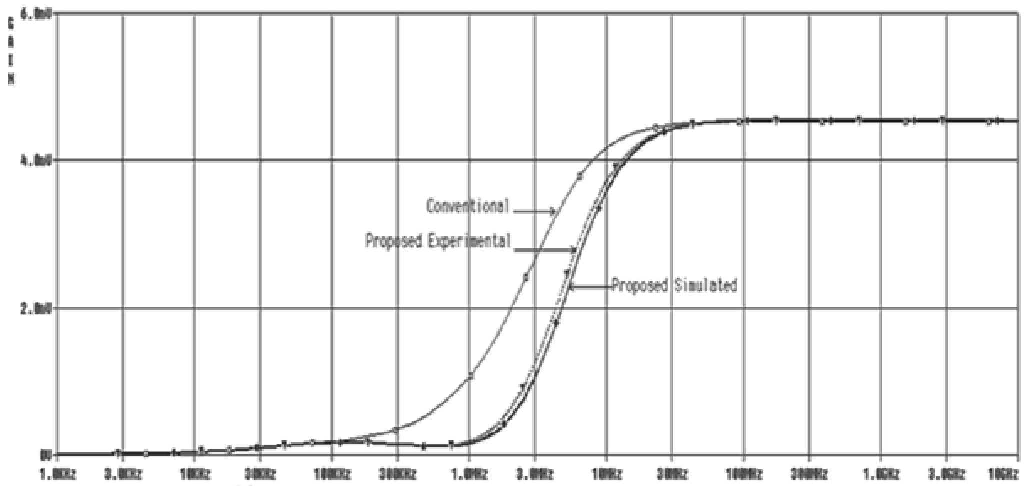
$R = 110k, \quad R_F = 110k$

$R_2 = 500\Omega$

The negative value for the resistor kR_2 was realized using a negative impedance converter.

A computer simulation of the circuit shown in Figure-2 for its magnitude response is plotted in Figure-3 with $G = 2$ and $k = k_m = -1$, and the lower cut-off frequency 340 kHz. The simulated magnitude response of the conventional high-pass filter shown in Figure-1 as well as the experimental data for the circuit shown in Figure-2 is also plotted in Figure-3 to facilitate comparison.

It is seen from Figure-3 that the magnitude response of the proposed circuit is much better than that of the conventional circuit. The experimental data plotted in Figure-3 are seen to be in close agreement with the simulated curve for the circuit shown in Figure-2. The minor deviation of the experimental data from that of the simulated curve may be attributed to the mismatching of op-amps and the resistor values used in simulation



Frequency

Figure-3: Simulated and experimental magnitude response of circuit in Figure 1 & 2

A computer simulation of the circuit shown in Figure 2 for its phase response is plotted in Figure 4. The simulated phase response of the conventional circuit shown in Figure 1 as well as the experimental data for circuit shown in Figure 2 are also plotted in Figure 4 to facilitate comparison. It is seen from Figure 4 that the phase response of the proposed circuit is somewhat better than the conventional circuit. The experimental data plotted in Figure 4 are seen to be in close agreement with the simulated curve for circuit shown in Figure 2. The minor deviation of the experimental data with the simulated curve may be attributed to the mismatching of op-amps and their deviation from the parameters used in simulation.

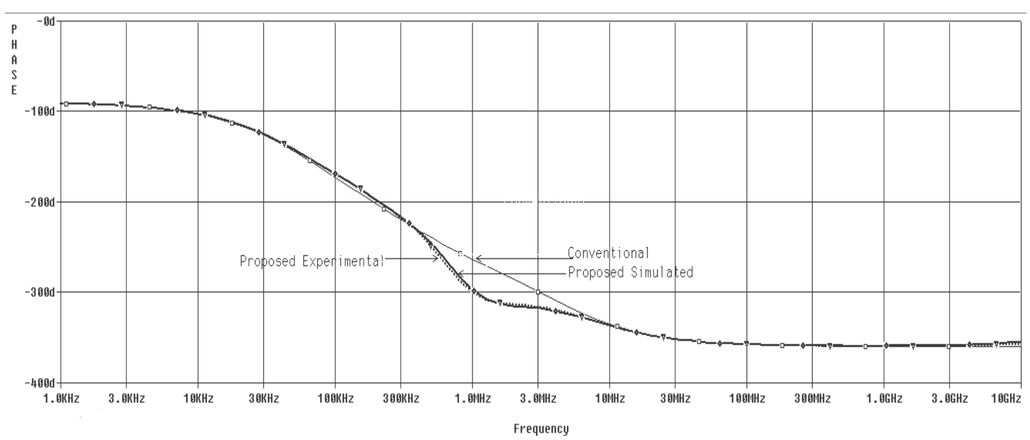


Figure 4: Simulated and Experimental Phase response of circuits of Figure 1 & 2

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